Is carotid angioplasty and stenting more cost effective than carotid endarterectomy?

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Objective: **Carotid angioplasty and stenting (CAS) has been advocated as a minimally invasive and inexpensive alternative to carotid endarterectomy (CEA). However, a precise comparative analysis of the immediate and long-term costs associated with these two procedures has not been performed. To accomplish this, a Markov decision analysis model was created to evaluate the relative cost effectiveness of these two interventions.**

Methods: **Procedural morbidity/mortality rate for CEA and costs (not charges) were derived from a retrospective review of consecutive patients treated at New York Presbyterian Hospital/Cornell (n = 447). Data for CAS were obtained from the literature. We incorporated into this model both the immediate procedural costs and the long-term cost of morbidities, such as stroke (major stroke in the first year = $52,019; in subsequent years = $27,336/y; minor stroke = $9419). We determined long-term survival rate in quality-adjusted life years and lifetime costs for a hypothetic cohort of 70-year-old patients undergoing either CEA or CAS. Our measure of outcome was the cost-effectiveness ratio.**

Results: **The immediate procedural costs of CEA and CAS were $7871 and $10,133 respectively. We assumed major plus minor stroke rates for CEA and CAS of 0.9% and 5%, respectively. We assumed a 30-day mortality rate of 0% for CEA and 1.2% for CAS. In our base case analysis, CEA was cost saving (lifetime savings = $7017/patient; increase in quality-adjusted life years saved = 0.16). Sensitivity analysis revealed major stroke and death rates as the major contributors to this differential in cost effectiveness. Procedural costs were less important, and minor stroke rates were least important. CAS became cost effective only if its major stroke and mortality rates were made equivalent to those of CEA.**

Conclusion: **CEA is cost saving compared with CAS. This is related to the higher rate of stroke with CAS and the high cost of stents and protection devices. To be economically competitive, the mortality and major stroke rates of CAS must be at least equivalent if not less than those of CEA. (J Vasc Surg 2003;37:331-9.)**

On the basis of the results of numerous published randomized trials, carotid endarterectomy (CEA) has been established as the "gold standard" in the treatment of stenotic lesions of the extracranial carotid arteries. However, in recent years, carotid angioplasty and stenting (CAS) has emerged as a new innovative and less invasive approach to the treatment of carotid artery stenosis.

Reported advantages of CAS include decreased cost, a shorter recovery period, diminished morbidity, and greater patient appeal.[1-4] Because of the limitations in healthcare resources and a plethora of expensive technology, enthusiasm for any new and potentially beneficial intervention must be tempered with a consideration of its cost. Policymakers and insurers must now consider not only whether new strategies for the treatment of patients improve quality of life but also whether these same practices are cost effective within a range deemed acceptable to society.

Decision analysis models that use morbidity, mortality, and cost as endpoints are powerful tools that can be used to validate the utility of a medical intervention. A critical element of decision analysis is its ability to assess both the immediate costs and outcome of an intervention and the long-term costs and sequelae. Although there have been previous attempts to evaluate the cost effectiveness of CAS versus CEA, in the studies published thus far, only costs associated with the initial hospitalization have been considered.[2,5] A formal cost-effectiveness analysis has not been performed.

To this end, we have developed a comprehensive Markov model that incorporates not only the cost incurred during the initial hospitalization but also the costs of complications, subsequent interventions, and long-term outcomes of patients undergoing either CAS or CEA. The goal of this analysis was to determine whether CAS is a cost effective alternative to CEA in the treatment of carotid stenosis.

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MATERIALS AND METHODS

Decision analysis model

We have developed a decision analysis model that reflects the possible clinical outcomes and costs associated with a hypothetic 70-year-old cohort of patients with ca-

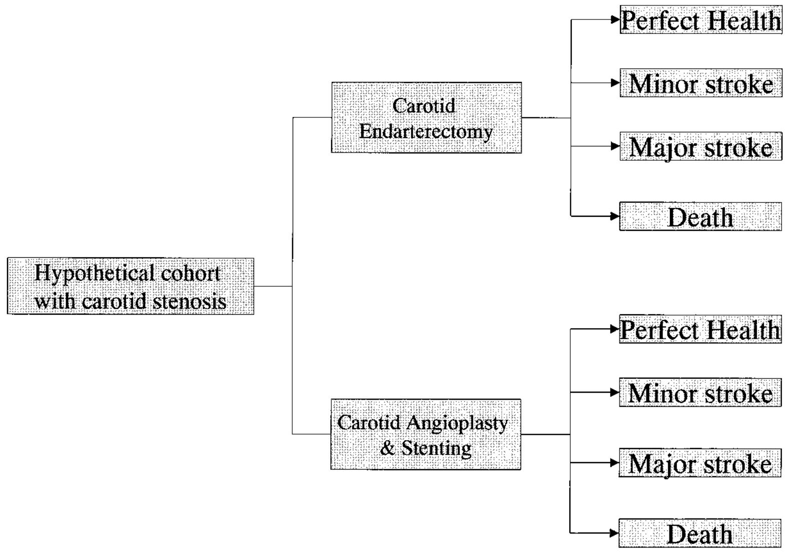

Fig 1. Simplified Markov decision analysis model. Hypothetic 70-year-old cohort of patients with carotid artery stenosis was randomly assigned to undergo either CEA or CAS. Treatment with either strategy was associated with numerous possible 30-day outcomes, including perfect health, minor and major stroke, or death.

Table I. Analysis of cost effectiveness of new strategy (CAS) versus alternative (CEA)

Costs	*Effectiveness*	*Conclusions*
↑	↓	Do not adopt
↑	↑	Determine CER; adopt if < \$60,000
↓	↑	Adopt

CER, Cost-effectiveness ratio.

rotid artery stenosis. Patients were randomly assigned to undergo either CEA or CAS (Fig 1). Selection criteria for CEA and CAS were carotid stenoses greater than 70% (symptomatic) or 80% (asymptomatic). Treatment with either strategy was associated with numerous possible 30-day outcomes, including perfect health, minor or major stroke (as defined in the North American Symptomatic Carotid Endarterectomy Trial), or death. The definition of major and minor stroke was on the basis of the Rankin score. These various outcomes formed the "branches" of a decision tree (Fig 1). A probability of occurrence and cost was assigned to each branch. With a computerized Markov decision analysis model (DATA 3.5.4, Treeage software, Inc, Williamstown, Mass; 1998), all of the possible clinical events and outcomes that occurred in both groups of patients were tracked and compared. The Markov model allows these patients to be followed until death. All the costs were converted to 1997 US dollars with the medical care component of the Consumer Price Index for All Urban Consumers. In accordance with standard principles of economic analysis, the costs and life expectancies were discounted at 3% per year to reflect the greater value of current dollars and life years as compared with that of the future.[6]

Our measure of outcome was the cost effectiveness ratio, which is defined as the difference in lifetime costs divided by the difference in life expectancy incurred by two interventions. Interventions can be discarded or adopted on the basis of their costs and effectiveness (Table I).

In the initial (base case) analysis, probabilities, and costs were derived from patients undergoing CEA at New York Presbyterian Hospital and the New York Presbyterian Hospital cost accounting system. The quality-adjustment factors were derived from the literature. With the realization that probabilities and costs may vary between surgeons and institutions, in sensitivity analysis, we systematically varied these assumptions through a wide plausible range and tested the effect of these variations on the base case conclusions. Because most widely accepted medical interventions have cost-effectiveness ratios of less than \$60,000 (Table II), we considered this value to be the threshold for our sensitivity analysis.[7]

Base case assumptions

Probabilities. Carotid endarterectomy data were obtained from a retrospective review of 447 CEAs performed at New York Presbyterian Hospital from 1997 to 2001. The probabilities for CAS including complications were obtained from recent reports from the literature.

The 30-day probability of stroke and death for patients undergoing CEA was 0.9% (major stroke, 0.45%; minor stroke, 0.45%; and death, 0%). We assumed for CAS a 30-day probability of stroke and death of 6.2% (major stroke, 1.8%; minor stroke, 3.2%; and death, 1.2%). Values for CAS were derived from an average of data obtained from recent peer reviewed published reports[3,5,8-10] (Table III). The incidence rate of myocardial infarction in the CEA group was 1.1%. None of the patients with infarction were symptomatic, and all cases were detected through perfunctory performance of enzyme analysis or electrocardiogram. We assumed the rate of myocardial infarction was 0.8% in the CAS group on the basis of a review of the available literature.[11] Reexploration for a neck hematoma occurred in only one patient in the CEA group (0.2%). We assumed the incidence rate of groin hematoma necessitating intervention to be 0.8% in the CAS group on the basis of data from several reports.[12] We assumed for CAS the rate of restenosis necessitating reintervention to be 3%[13] and that for CEA to be 1%. We assumed that all reinterventions for restenosis were treated with carotid stenting. Eight cranial nerve injuries (1.7%) were noted in the CEA group, all of which were transient (Table IV).

Costs. ***Procedural costs.*** We determined procedural costs with evaluation first of resource utilization for each procedure and then multiplication of total utilization by unit cost (Table V). As an example, the average operating room cost per patient for CEA was determined by multiplying an average operating room time (time the room was occupied) of 228 minutes by a calculated operating room cost of $1372 per hour for the first hour and $230 for each additional half hour. Resource utilization for CAS was obtained from the literature. However, the cost of resources for CAS, such as the angiography suite, was also obtained from the cost accounting system at New York Presbyterian Hospital. Professional fees were derived from the Medicare reimbursement for the year 2002 for the appropriate Current Procedural Terminology codes. The procedural cost of CEA, including anesthesia, was estimated at $7871 on the basis of the last 447 procedures performed at this institution. The average cost of CAS was calculated to be $10,133. The average time for CAS was estimated to be 90 minutes.[14-16] We identified the sheaths, catheters, guidewires, and balloons that are used in a typical procedure and determined the costs for these various items by averaging prices from multiple vendors (Table V). We used the cost of an angiography suite at our institution of $1100 for the first hour and $300 for each subsequent half hour. The professional fee for the interventionalist was calculated to be $1242. Additional costs assigned to CAS included the costs of a stent, a cerebral protection device, and an arterial closure device. The average length of stay for patients for CAS was assumed to be 1.9 days and included additional length of stay related to complications.[15,16] We assumed that 15% of patients would spend at least 24 hours in the intensive care unit for blood pressure monitoring and that the remaining 85% would be monitored in a telemetry unit before discharge (cost of telemetry unit bed/day, $1140)

Cost of morbidity. Direct costs of stroke were estimated from the literature. With these assumptions, we derived a cost of $52,019 for the first year after a major stroke and an annual cost of $27,336 for subsequent years. We used $9419 as the average cost for patients with minor strokes. For a clinically significant myocardial infarction, we estimated a cost of $11,000 for the first year and $2800 for each year thereafter.[12,13] We assumed 120 minutes of operative time for wound exploration for hematomas at a cost of $1700 (Table IV). In general, postoperative complications that were not associated with long-term sequelae, such as small hematomas, produced an increase in length of stay but had no economic impact.

Table II. Cost-effectiveness ratios for common medical practices

Medical intervention	*Cost-effectiveness ratio ($/QALY)*
CEA for patients who are symptomatic	4600
CABG for left main disease	9500
Endovascular repair of 5-cm AAA	22,826
Hemodialysis for ESRD	54,400
CEA for patients who are asymptomatic	58,600
Routine cell saver device for elective AAA	120,800
Orthotopic liver transplant for hepatocellular cancer	136,900

QALY, Quality-adjusted life year; *CABG*, coronary artery bypass grafting; *AAA*, abdominal aortic aneurysm; *ESRD*, end-stage renal disease.

Quality adjustment. The outcome most often used in cost-effectiveness analysis is quality-adjusted life expectancy, which is measured in quality-adjusted life years. Because the quality of life associated with some health states may be less desirable than those of others, life expectancy is adjusted for quality of life. The quality-adjustment factor may range from 0 (death) to 1 (perfect health). We used a quality-adjustment factor of 0.40 for patients who survived a major stroke.[17] Patients who had a minor stroke were assigned a disutility of 0.25 years, meaning that 3 months were subtracted from their overall quality-adjusted life expectancy. We assumed a quality-adjustment factor of 0.88 for myocardial infarction.[18] Cranial nerve injuries were assigned a disutility of 0.15 years. We assumed a disutility of 2 days for CAS and 2 weeks for CEA.

RESULTS

Base case analysis. With our base case assumptions, we calculated the life expectancy and lifetime costs for a hypothetic cohort of patients undergoing either CAS or CEA. The survival of patients after CAS, calculated in quality-adjusted life years, was 8.20 and after CEA was 8.36. Thus, patients undergoing CEA lived 0.16 years longer than those undergoing CAS. The lifetime costs for CAS and CEA were $35,789 and $28,772, respectively. Thus, CAS was $7017 more costly (over a patient's lifetime) than CEA. Because CEA resulted in a greater life expectancy and cost less than CAS, we considered CEA to be cost saving. In other words, CEA was the optimal procedure both in terms of cost and life expectancy.

Sensitivity analyses. With the realization that the variables that we chose for our base case analysis may vary

Table III. Studies used for base case analysis for CAS

Author	*Dates*	*No. of patients*	*No. of arteries*	*Study design*	*Years of study*
Diethrich[8]	1996	110	117	Nonrandomized prospective	1993-1995
Wholey[3]	1997	108	114	Nonrandomized prospective	1993-1995
Jordan[5]	1998	109	109	Retrospective	1994-1995
Henry[9]	1998	163	174	Nonrandomized prospective	1995-1998
Roubin[10]	2001	528	604	Nonrandomized prospective	1994-1999

Table IV. Value of variables chosen for base case analysis

Variables	*CEA*	*CAS*	*CEA and CAS*
Probabilities			
Mortality	0%	1.2%	
Major stroke	0.45%	1.8%	
Minor stroke	0.45%	3.2%	
MI	1.1%	0.8%	
Hematomas	2.68%	0.8%	
Restenosis	1%	3%	
Cranial nerve injuries	1.78%	0%	
Costs			
Hospitalization	$7871	$10,133	
Major stroke			$52,019/27,336
Minor stroke			$9419
Reoperation for hematoma			$1700
Cranial nerve injury	$9500		Assumed
Quality-adjustment factors			
Stroke			0.40
MI			0.88
Cranial nerve injury			0.85

MI, Myocardial infarction.

between institutions and physicians practices, we performed sensitivity analyses to evaluate the effect of wide variations in costs and event rates on the outcome of our analysis (Table VI). Our goal was to determine which of the variables had the greatest impact on cost effectiveness.

In our base case analysis, we assigned a mortality rate of 0% for CEA and 1.2% for CAS. Even if the mortality rate for CAS was decreased to that of CEA, CEA still remained cost saving. We assigned a perioperative risk of major stroke of 0.45% for CEA and 1.8% for CAS. If the rate of major stroke for CAS decreased to that of CEA (0.45%), CEA remained cost saving. We assigned a perioperative risk of minor stroke of 0.45% for CEA and 3.2% with CAS. Once again, if the rate of minor stroke for CAS was reduced to that of CEA, CEA remained cost savings. And finally, for our base case analysis, we used a procedural cost of $7871 for CEA and $10,133 for CAS. If the procedural cost of CAS was reduced to that of CEA, CEA remained cost saving. Thus, in one-way sensitivity analyses, CEA remained cost saving despite the establishment of equivalence for CEA and CAS of any individual variable (Table VI).

With the advent of lower profile stents and improved cerebral protection, the combined morbidity and mortality associated with CAS could potentially approach that of CEA. Thus, in our next analysis, we simultaneously decreased the major and minor stroke rates and the mortality rate of CAS to levels equivalent to that of CEA. This resulted in a cost-effectiveness ratio for CAS of $68,800, a value that approaches the range of accepted medical interventions (we choose $60,000 as our threshold).

With the assumption of equivalent major mortality and morbidity for the two procedures, we then searched for additional variables that might enhance the cost effectiveness of CAS. Factors that appeared to be important were the procedural costs of CAS and the disutility, or days of incapacitation, related to the two procedures. Regarding the latter, in our base case analysis, we assumed that CAS would produce 2 days of incapacitation or the loss of 2 days of life from the overall life expectancy of patients undergoing this procedure. We assumed that CEA would result in 14 days of incapacitation, or the loss of 14 days of life from patients undergoing CEA. Again, assuming equivalent morbidity and mortality for the two procedures, we varied the disutility assigned to CEA. If the disutility for CEA was increased from 14 days to 21 days, CAS then became extremely cost effective with a cost-effective ratio of $39,315. Thus, if equipoise can be achieved between CEA and CAS with regard to mortality and morbidity and one assumes a disutility for surgery of 3 weeks, CAS becomes the preferred procedure in terms of cost effectiveness.

We next sought to determine the variables in our model that had the most substantial effect on lifetime

Table V. Cost breakdown for CEA and CAS

		Utilization/patient		*Total cost/patient*	
	Unit cost	*CEA*	*CAS*	*CEA*	*CAS*
Operating room	$1373/first h $230/each subsequent 30 min	228 min		$2660	
Angio suite	$1100/first h $300/each subsequent 30 min		90 min		$1400
EEG	$430	1		$430	
TCD	$275		1		$275
Shunt	$110	5%		$5	
Patch	$310	1		$310	
Vessel loops	$2.80	5		$14	
Sutures	$5	5		$25	
Endovascular equipment					
Conray dye	$168/100 mL		125 mL		$210
Vessel puncture kit	$28		1		$28
5F sheath	$18		1		$18
260-cm 0.035 in glidewire	$52		1		$52
Pig-tail catheter	$18		1		$18
Power injector tubing	$5		2		$10
VTK or head hunter or vertebral catheter or angled glidewire	$20		1		$20
260-cm Amplatz	$47		1		$47
BMW 0.014 in wire or choice floppy or choice extra support	$105		1		$105
90-cm Shuttle sheath or 80-cm Raabe sheath or H-1 guide sheath	$110		1		$110
5 × 2 Savvy balloon or 4 × 2 cross sail balloon or 4 × 2 ranger balloon	$390		1		$390
Balloon insufflator	$90		1		$90
Torque device	$8		1	$8	
8 × 4 Precise stent or Dynalink stent or Precise taper stent	$1800		1		$1800
Percusurg embolic protection device or Angiogaurd or EPI filter	$1600		1		$1600
Femoral puncture closure device: Perclose or angioseal or vasoseal	$190		1		$190
Surgeon/interventionalist reimbursement (Medicare-2002)				$1285	$1242
Anesthesia reimbursement	$23/unit	26 units		$600	
Postoperative					
ICU	$1500/d	9%	9.8%	$336	$225
Telemetry unit	$1140/d		90.2%		$1995
PACU	$1100/d	6%		$183	
Ward	$930/d	85%		$2022	
Hospitalization cost				$2542	$2220
Plavix (75 mg/d for 4 wks)					$150
Total costs				$7871	$10,133

EEG, Electroencephalography; *TCD*, transcranial Doppler; *VTK*, VITEK; *BMW*, Balance Middleweight Universal guidewire; *ICU*, intensive care unit; *PACU*, postanesthesia care unit.

costs and life expectancy. We first evaluated the effect of variations in the rate of major and minor stroke on the lifetime cost of CAS (Fig 2). We found that major strokes had a profound impact on lifetime costs whereas minor strokes had a negligible effect. We also determined which variables had the most profound impact on life expectancy after CAS (Fig 3). Not surprisingly, we found that the major stroke rate and perioperative mortality rate had the most significant impact on life expectancy. Minor stroke again had minimal impact. These data show that the cost effectiveness of CAS is critically dependent on the major stroke rate and on procedural costs and mortality. The rate of minor stroke was less important than these other variables.

We varied the reintervention rates for CAS and CEA (base case reintervention rate: CAS, 3%; CEA, 1%) in sensitivity analysis and found little impact on the outcome of our analysis. We also varied the age of the hypothetic patient cohort from 50 through 90 years. With the assumption that all other variables remained constant, the cost effectiveness of CEA was further enhanced in patients who were less than 70 years of age. However, CEA remained cost saving even in patients up to 90 years of age.

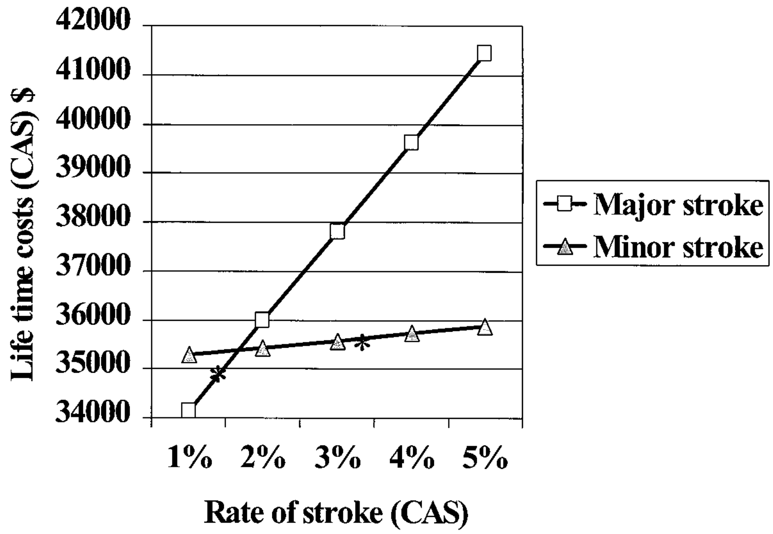

Fig 2. Impact of rate of major and minor stroke associated with CAS on lifetime costs of CAS. *Value assumed in base case analysis.

Table VI. Range of variables tested in sensitivity analysis

Variable	*CEA base case*	*CAS base case*	*Range**
Mortality	0%	1.2%	0-5%
Major stroke	0.45%	1.8%	0-5%
Minor stroke	0.45%	3.2%	0-10%
MI	1.1%	0.8%	0-5%
Age (y)	70	70	50-90
Procedure costs	$7689	$10,133	$5000-$15000

*Both CEA and CAS were varied over these ranges.
MI, Myocardial infarction.

DISCUSSION

Two previous attempts have been made to define and compare the costs associated with CEA and CAS.[6,9] However, both analyses were limited to the costs associated with the initial hospitalization. Moreover, in one of the two studies, charges were evaluated rather than costs.[5] To compare the true cost effectiveness of CEA and CAS in the management of carotid stenosis requires consideration of both lifetime costs and effectiveness. To this end, we constructed a Markov decision analysis model in which the strategies of CEA and CAS were compared. In our base case analysis, we found that CAS was more expensive than CEA. Moreover, CAS reduced rather than extended life expectancy. In other words, CAS costs more and is less effective than CEA. Consequently, a cost-effectiveness ratio could not be determined. Thus, we concluded that CEA is cost saving compared with CAS. In our initial analysis, we compared the costs and outcomes for CEA at a single institution with results reported in the literature for CAS. In determining the outcomes for CAS, we averaged the results of several modern studies performed by investigators with substantial experience with this technique. It could be argued that the outcomes of CEA that we used for this model were more favorable than those reported by large multicenter trials. However, the recent literature is replete with single institution series of CEA touting rates of stroke and death in the 0.5% to 2% range.[19-21] Moreover, the data that we report for CAS were also derived from single institutional experiences. We do recognize that morbidity, mortality, and costs will vary between surgeons and institutions. Moreover, the technology, expertise, and consequently, the results associated with CAS may improve over time. Accordingly, sensitivity analyses were performed to determine the influence of these variables on our base case conclusion. The immense benefit of a decision analysis model is its flexibility. The assignment of any variable can be changed, and the effect of this variation on outcome can be calculated.

We first analyzed the cost of the initial hospitalization for the two interventions. In our base case analysis, we found the cost of the initial hospitalization to be approximately 25% higher for CAS ($10,133) versus CEA ($7871). Although many variables were incorporated into this calculation, the most influential factors leading to this differential in cost were the stent and the protection device. The cost of a stent can range from $1400 to $1800, and the cost of a protection device is similar. With other "minimally invasive" vascular procedures, such as endovascular repair of abdominal aortic aneurysm, the additional expense of the device is offset, to some extent, by a decrease in the length of hospital stay. However, a similar benefit does not exist for CAS. The safety of an overnight stay for routine CEA has been repeatedly established. Although procedural times and length of stay may be modestly less with CAS, the cost savings associated with these variations is minor compared with the cost of a stent and protection device. For example, decreasing the procedural time for CAS from 90

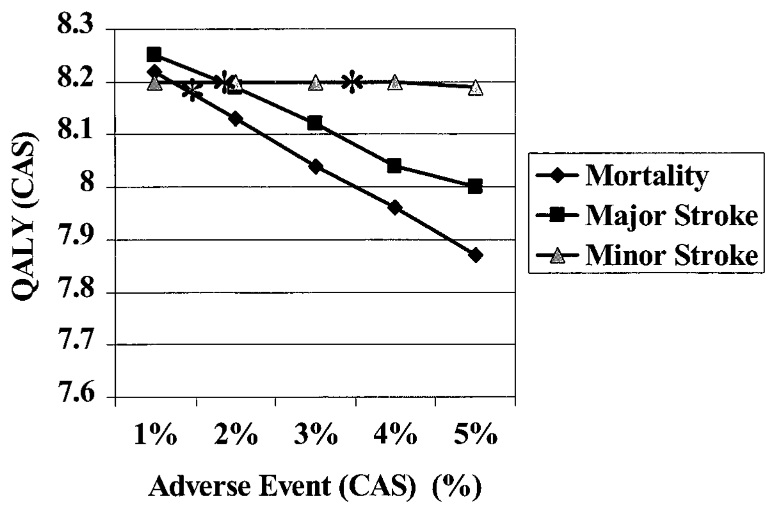

Fig 3. Impact of variations in mortality and major and minor stroke rates associated with CAS on quality of life years for CAS. *Value assumed in base case analysis. *QALY,* Quality-adjusted life year.

to 60 minutes (total room time) saves $230 per patient, a small number relative to a cost of $3200 for the stent and the protection device. It seems unlikely in the near future that the procedural costs of CAS will diminish to any great extent.

The cost associated with major morbidities is often overlooked when comparing the cost effectiveness of two interventions. The most prevalent morbidity associated with either CAS or CEA is stroke. The expense to society of a major stroke is substantial, as high as $160,000 per patient over a period of 5 years. Varying the rate of major stroke in sensitivity analyses had a substantial impact on both life expectancy of patients and cost (Fig 2). Interestingly, we found that varying the rate of minor stroke had little effect on the outcome of this analysis. Most minor strokes are transient, and the disutility from these events is not substantial. Moreover, the cost associated with minor strokes is relatively minor. This observation is important because, in many series of CAS, most strokes are minor. Thus, if rates of major stroke and death for CAS can be brought into the range of CEA, from a cost-effective standpoint, equipoise may be achieved.

The goal of the study was to create a model that allowed determination of the relative cost effectiveness of CEA and CAS. We believe that we have effectively accomplished this task in that our model includes all of the relevant variables that need to be considered. The issue that arises with any decision analysis model is the validity of the values that are chosen for these variables. The outcomes for CAS are still evolving. This may be true even for CEA. Recently reported rates of stroke with CEA are more favorable than those reported 10 years ago in the North American Symptomatic Carotid Endarterectomy Trial. Realistically, it will be at least 5 years before comparative level I data are available for both techniques. In the absence of level one data, decision analysis techniques have been used extensively to evaluate many new technologies. The onus is on the authors of such models to make the best assumptions possible. Moreover, sensitivity analyses function as an important tool to allow evaluation of the effect of a variety of different clinical scenarios on the model's outcome. We were able to predict from this model, on the basis of sensitivity analyses, that the major stroke and mortality of CAS must approach that of CEA before there can be parity in cost effectiveness. This conclusion is the thrust of the manuscript and can be made regardless of the variables chosen for the base case analysis.

Is it possible that the demand for CAS because of its "minimally invasive" nature will overwhelm any consideration of cost? There are in fact few rules regarding what society is willing to pay for new medical interventions. Patient demand can to a great extent drive the availability of resources. Hospitals may offer patients cutting edge technology, despite a loss in revenue, so as to maintain dominance in the treatment of a particular type of disease. Moreover, Medicare and other insurers, related to patient desire, may choose to reimburse carotid stenting even if the costs are higher. However, with the plethora of new technology that is now available and limited healthcare resources, it is safe to assume that cost will continue to play an important role in such decisions.

When additional experience with CAS is gained, more definitive data regarding costs and outcome can be applied to this or similar models. However, this analysis suggests that, to be economically competitive with CEA, CAS must be performed with mortality and stroke rates that are less than those of CEA. A true assessment of the cost effectiveness of CAS will not be achievable until more definitive long-term trials, such as the Carotid Revascularization Endarterectomy Versus Stent Trial, have been completed.

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DISCUSSION

Dr Richard M. Green (Rochester, NY). One could take the approach that this is a very self-serving kind of analysis because you are a surgeon and there are other technologies that we are embarking on and they are going to cost more. So, what should we do, abandon the technologies?

Dr Sashi Kilaru. I do not think that is the emphasis of the paper. I think this paper looks at it at a societal level to see if in fact it is cost effective. All we are trying to say at this time frame is that it is not cost effective. With newer generation devices, it in fact may become more cost effective and so it should be adopted. I think at this point it should be done only in clinical trials in a fixed setting.

Dr Wilhelm Sandmann (Dusseldorf, Germany). I think this was a very interesting analysis and probably gives some good thoughts for the future.

Almost 20 years ago when we presented in Europe our experience with carotid endarterectomy with only Doppler examination, Dr Anthony Imparato, who was an invited speaker to this meeting in Bern, Switzerland, criticized at that time that if we would continue to perform this operation without angiography we would be very irresponsible. Today I have the impression that even in the United States many more vascular surgeons do not use arteriography, but how does arteriography or only noninvasive examination have influence on your calculations? Did you calculate for any carotid endarterectomy the costs of arteriography as well, or could this be subtracted because then CEA would be much cheaper?

Dr Kilaru. That is an excellent point. In our analyses, most of these endarterectomies were done with preoperative Doppler examination only. We found more than actually just that cost. The long-term costs were the ones that had the most significant impact on the model (ie, the major stroke rate). I agree that if these are done only under Doppler, this is probably a way towards endarterectomy.

Dr Gerald M. Baur (Boise, Idaho). Can you tell us whether the costs that you are talking about in this paper are true costs, hospital costs, or are they charges? One is real, one is artificial.

Dr Kilaru. That is a very important point. And we specifically use only cost, because our charges vary from hospital to hospital and they may vary within the hospital itself. So, this was specifically cost only and not charges.

Dr Frank B. Pomposelli (Boston, Mass). Your control group was comprised of data obtained from the outcome of carotid endarterectomy at New York Hospital, which is a center of excellence for treatment of vascular disease. What happens if you used the data comparable with the outcomes from the study from Cincinnati that Tom Brott reported some years ago where the average stroke rate for carotid surgery was 10%? Other studies have similarly shown that what happens in large centers with large experiences does not necessarily reflect what is happening around the country.

Dr Kilaru. That is an excellent point. We tested this in sensitivity analysis whereby we decreased the CAS rates that we obtained from the literature to the stroke rates that are found in our institution and did not find any difference in our conclusion. However, if there is a single center that performs both these procedures and if, in fact, the stroke rates associated with angioplasty and stenting are much better in that institution, most certainly angioplasty and stenting should be performed. I think at this time frame, since CAS is a more expensive procedure, it has to have lower stroke rates for it to be cost effective.

Dr James C. Stanley (Ann Arbor, Mich). Most healthcare analysts consider an operative intervention or medical-drug therapy to be cost effective when the expense does not exceed $50,000 a year. You are not too far from that with carotid angioplasty and stenting. Although your figures may favor carotid endarterectomy, some practitioners and providers may view the cost of carotid angioplasty and stenting as a reasonable expense to justify the procedure. What is your perspective on the customary cost-effective break point?

Dr Kilaru. The clear cutoff point whereby a procedure is cost effective versus not cost effective is not spelled out in stone. It is anywhere between $50,000 to $60,000. We found that the only way, with the present rates that we used in our data, that angioplasty and stenting would have a cost-effective ratio around $68,000, provided that the stroke rates and everything were equivalent to endarterectomy.